Vehicle-to-Vehicle MIMO Channel Measurements and Modelling

Dr. Xiang Cheng（程 翔）

Wireless Communication and Signal Processing Research Center

School of Electronics Engineering and Computing Science

Peking University

Email: xiangcheng.86@googlemail.com

Outline

I. Motivation and Background

II. V2V MIMO Channel Measurements and Modelling

III. Challenges and Future Work

I. Motivation and Background

Motivation 1: Traffic Accidents

About 6 million traffic accidents occur each year in the USA, which accounts for $230 billion in damaged property, 2,889,000 nonfatal injuries, and 42,643 deaths.

Safe belt

Air bag

PASSIVE approach!

Can we do something in an **ACTIVE** manner?

Motivation 2: Traffic Congestion

A new and better system:

V2V Communication system is necessary!

- Odd-even traffic restriction

- Sitting in traffic congestion costs travelers and businesses about $40 billion each year in the USA.
  - Petrol wasted – more pollution!
  - Time wasted!
- **Can we do anything better?**

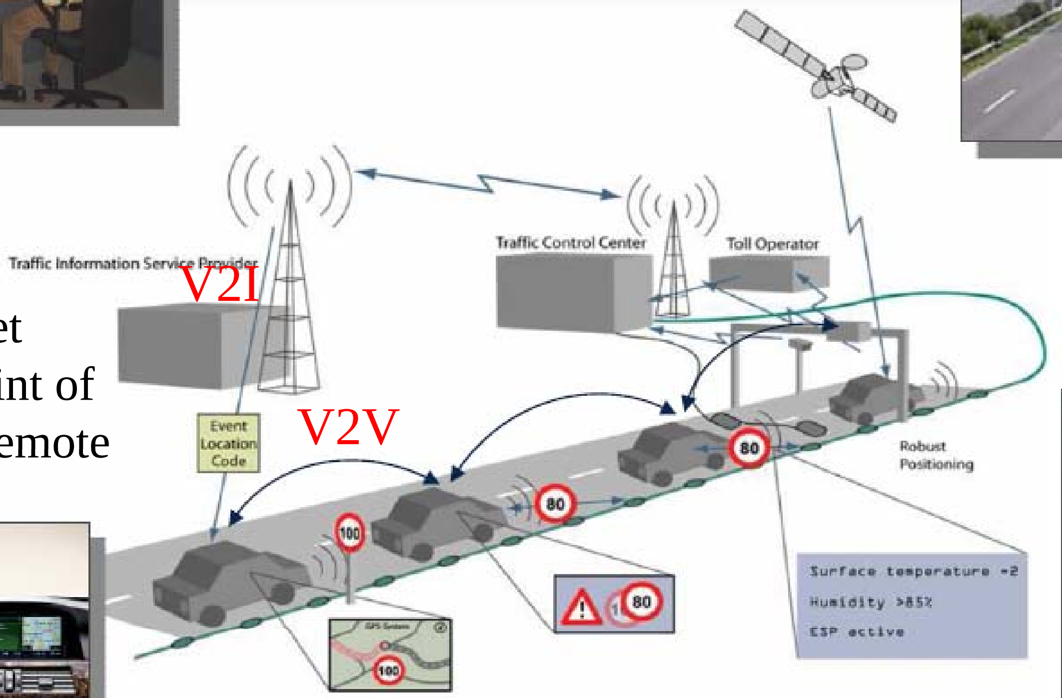
- Expensive parking

Applications

Active Safety: Cooperative forward collision warning, pre-crash sensing/warning, hazardous location M2M notification.

Traffic Efficiency: enhanced route guidance and navigation, M2M merging assistance.

Infotainment: internet access in vehicles, point of interest notification, remote diagnostics.



Source: COOPERS project

Traffic Efficiency: green light optimal speed advisory.

V2V System Protocol Stack and Functionality

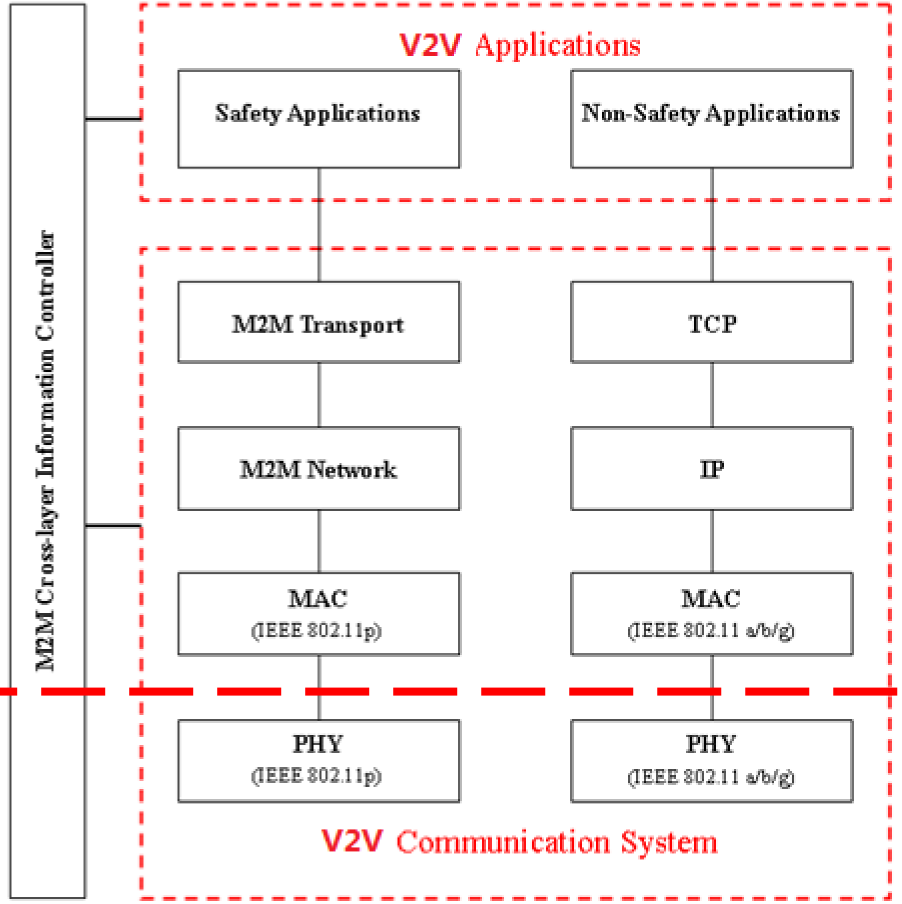
IEEE P1556

IEEE P1609

WAVE

IEEE 802.11p

DSRC



Enabling foundation for practical design of V2V systems.

Accurate yet easy-to-use V2V channel model

II. V2V MIMO Channel Measurements and Modelling

Prof. Sana Salous

Focus: channel measurement

(Chirp Channel Sounder)

Dr. David Laurenson

Focus: data post-processing

Dr. Cheng-Xiang Wang

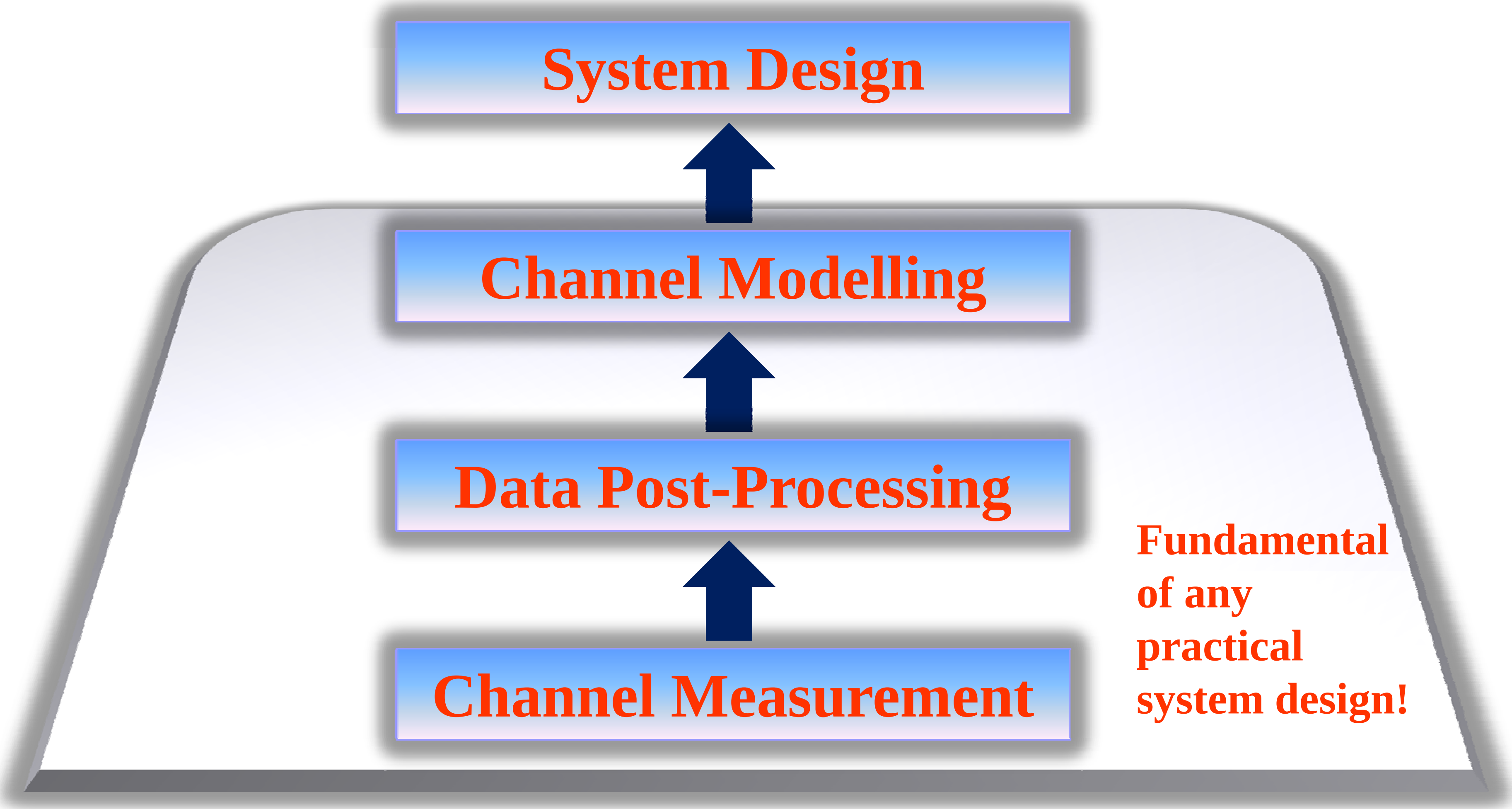
Focus: channel modelling and simulation

Dr. Xiang Cheng (Prof. Bin-Li Jiao, Prof. Yuping Zhao, and Prof. Lingyang Song)

Focus: channel modelling and system design

A successful and practical design of any system has to be adapted to the properties of the propagation channels （time-varying joint Doppler-delay-angle spread).

General Process of A System Design



Important V2V Propagation Scenarios

- **Road characteristics：**
  - Urban, suburban, rural.
  - Highway, tunnel.
- **Traffic characteristics：**
  - Two vehicles drive in same or opposite directions.
  - Vehicular traffic density (VTD)：high, medium, low.
- **Application-specific scenarios：**
  - Pre-crash warning：1）intersection collision avoidance；
    2）cooperative merging assistance.
  - Post-crash warning：slow traffic warning.

Current Important V2V Channel Measurements

Measurement	Antenna	Carrier frequency	Frequency selectivity	Tx-Rx direction	Environments
[Aco04] Glob…	SISO	2.4 GHz	Wideband	Same	SS/EW (Pic), LVTD
[Za… TVT	Omni-				LVTD
[Mat08] C…	SISO	5 GHz	Wideband	Same	UC/SS/EW …ic+Pic) …(L)VTD
[Pai08] WPC	Omni-				…EW (Pic) LVTD
[Ch… JSAC					LVTD
[Aco07] VTM	Omni-		…d	Same+ opposite	UC/SS/EW (Mic +Pic) LVTD
[Pai10] VTC	MIMO Dire-	5.2GHz	Wideband	perpendicular	IS(Mic+Pic) HVTD

Shadowing by other vehicles

…nario

High Doppler shifts

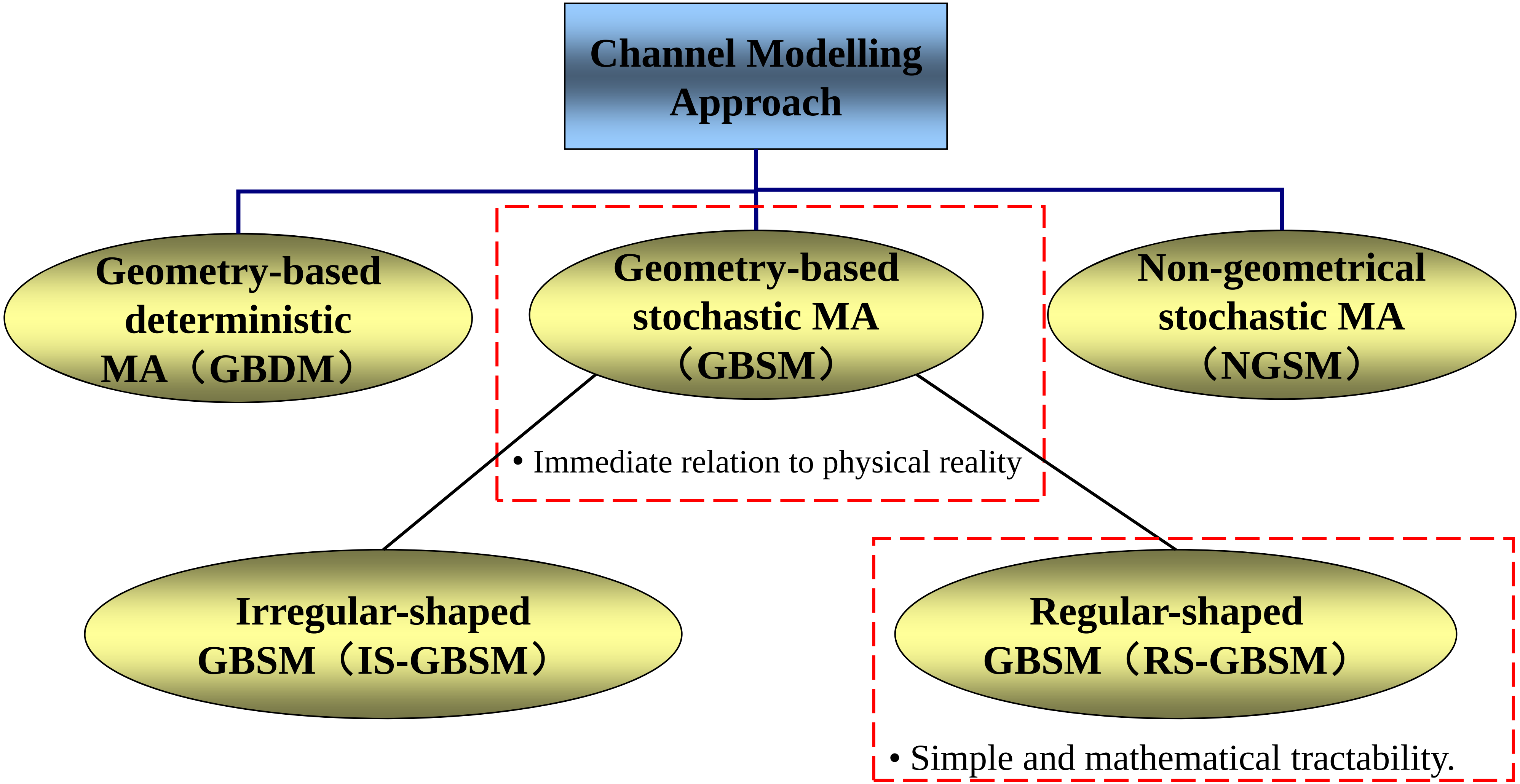
Application-specific scenario

Inherent non-stationarity

Directive antenna

UC: urban canyon;
SS: suburban street;
EW: expressway;
H(L)VTD: high (low) vehicular traffic density;
Omni-: omni-directional antenna;
Dire-: directive antenna.

Channel Modelling Apporach



Current Important V2V Channel Models

Channel m	Antenna and	Stationarity	Impact of VTD	Per-tap CS	Scatterer region/ distribution	Scattering assumption	Applicable scenarios
[Mau08] GBDM	MIMO wideband	non-stationary	yes	no	2D non-isotropic (deterministic)	SB+MB	site-specific
[A N			no		n-isotropi N/A)		
[Mat08] NGSM	SISO	non-	yes	yes	2D non-isotropic	N/A	Mic+Pic
[Akk86] RS-GBSM						DB	Mac
[Zaj08] RS-GBSM	narrowband				(two-ring)	B+DB	Mac+Mic
[Zaj09] RS-GBSM	MIMO wideband	statio			isotropic ylinder)	SB+DB	Mac+Mic

RS-GBSM:

Impact of VTD

Pico-cell

Per-tap CS

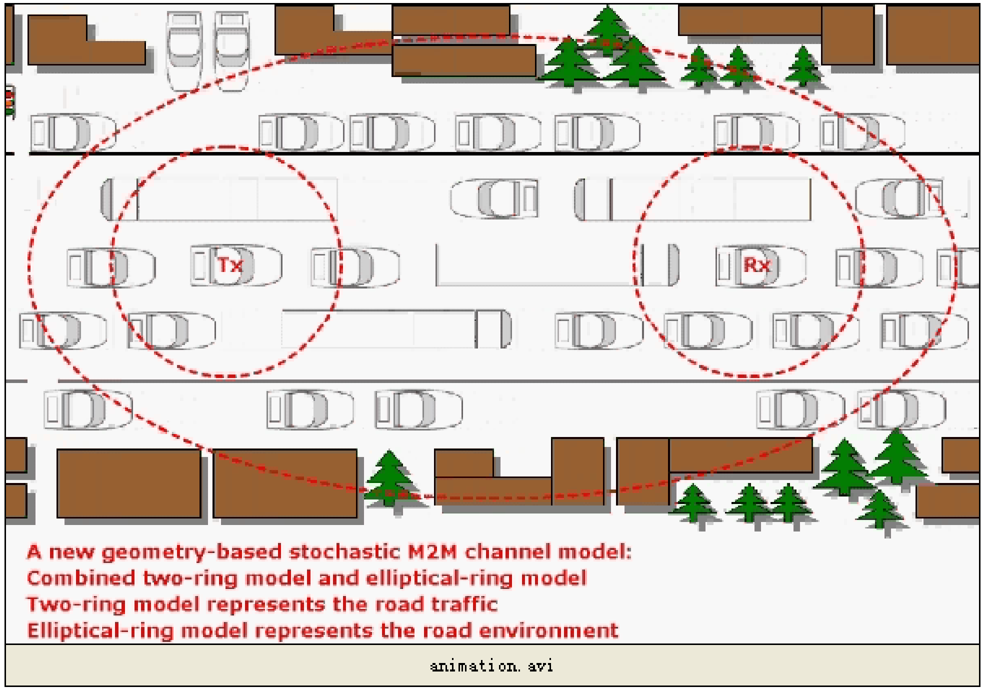
Relationship between azimuth and elevation angles

Non-staionarity

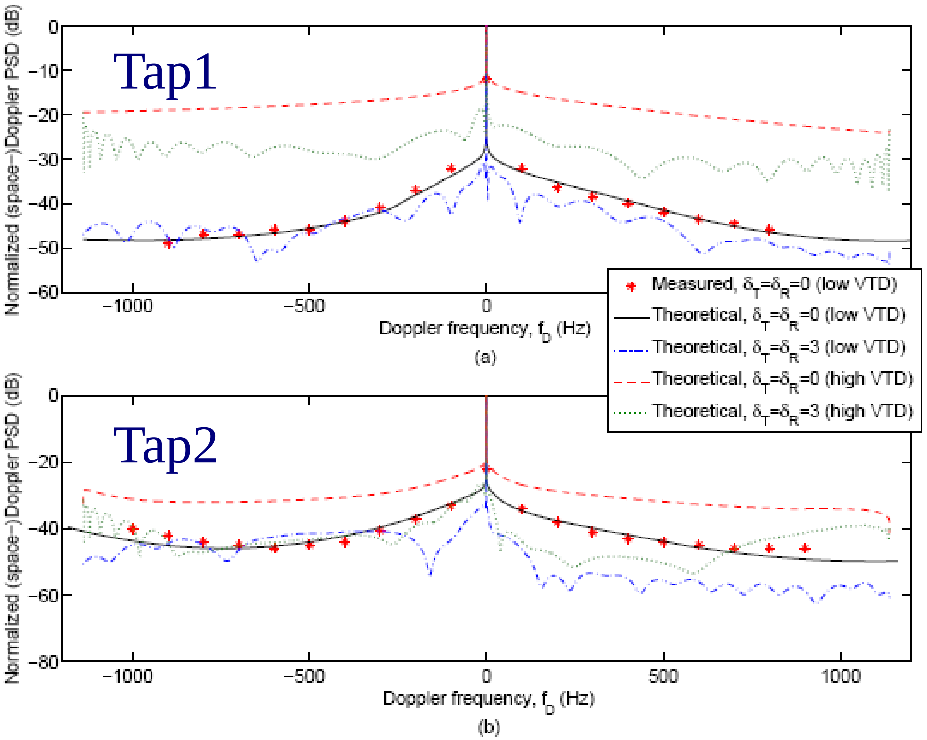
GBDM: geometry-based deterministic model; **NGSM**: non-geometrical stochastic model; **GBSM**: geometry-based stochastic model; **FS**: frequency selectivity; **CS**: channel statistics; **SB**: single-bounced; **MB**: multiple-bounced; **DB**: double-bounced; **N/A**: not-applicable; **Mac**: Macro-cell; **Mic**: Micro-cell; **Pic**: Pico-cell.

A New 2D V2V MIMO RS-GBSM and Its Extension

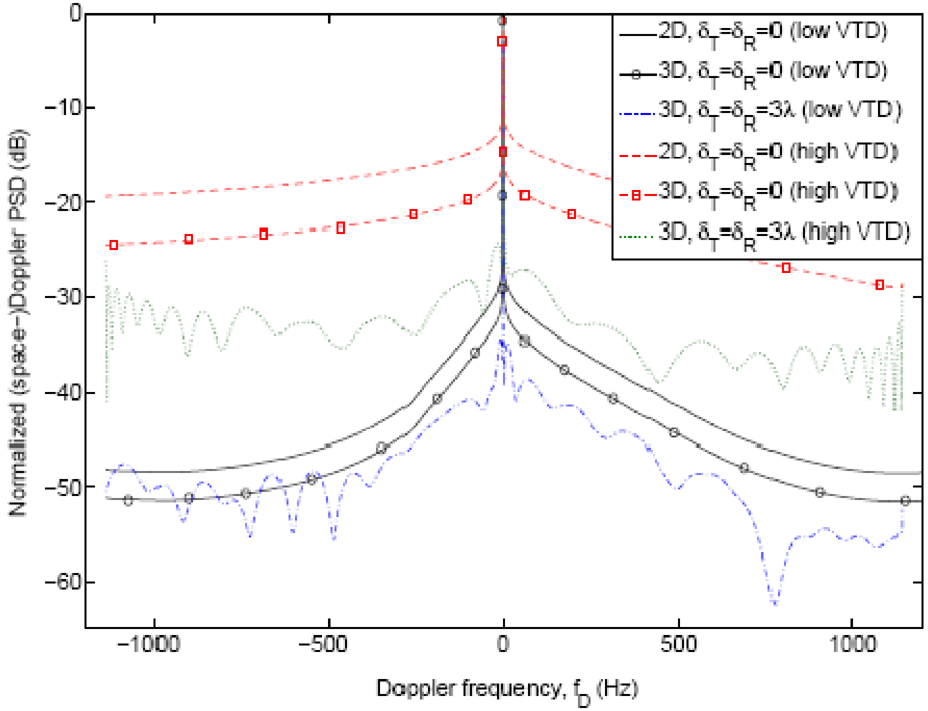
- Channel fading envelope: $h_{pq}(t) = h_{pq}^{LoS}(t) + h_{pq}^{SB}(t) + h_{pq}^{DB}(t)$
- **Impact of VTD**: distinguish between the moving cars and stationary roadside environments.
- **Pico-cell**: derive a novel generic relationship between the AoA and AoD for a wide variety of scenarios .
- Extension to 2D wideband model by incorporating frequency selectivity.
  - **Per-tap channel statistics**: utilise the TDL structure.
- Extension to 3D model.
  - **Relationship between azimuth and elevation angles**: apply von Mises Fisher distribution.



Numerical Results and Analysis



Normalized (space-)Doppler PSD, same direction.



Normalized (space-)Doppler PSD, same direction.

- Close agreement between the theoretical results and measurement data confirms the utility of the proposed model.
- Higher VTDs result in more evenly distributed (space-)Doppler PSDs.
- 2D model underestimates both the temporal and spatial diversity gains.

Challenges and Future Work (I)

- More channel measurements for important V2V communication scenarios
  - Impact of VTD on channel statistics.
  - Tunnel and application-specific scenarios.
  - Impact of elevation angle on channel statistics.
  - Particularity of V2V communication scenarios in China, e.g., viaduct scenarios.
- Non-stationarity of V2V channels
  - Current approaches: 1) based on TDL structure; 2) based on GBSM.
  - Is there an approach to essentially solve this problem?
- Impact of antenna pattern and location on channel statistics.

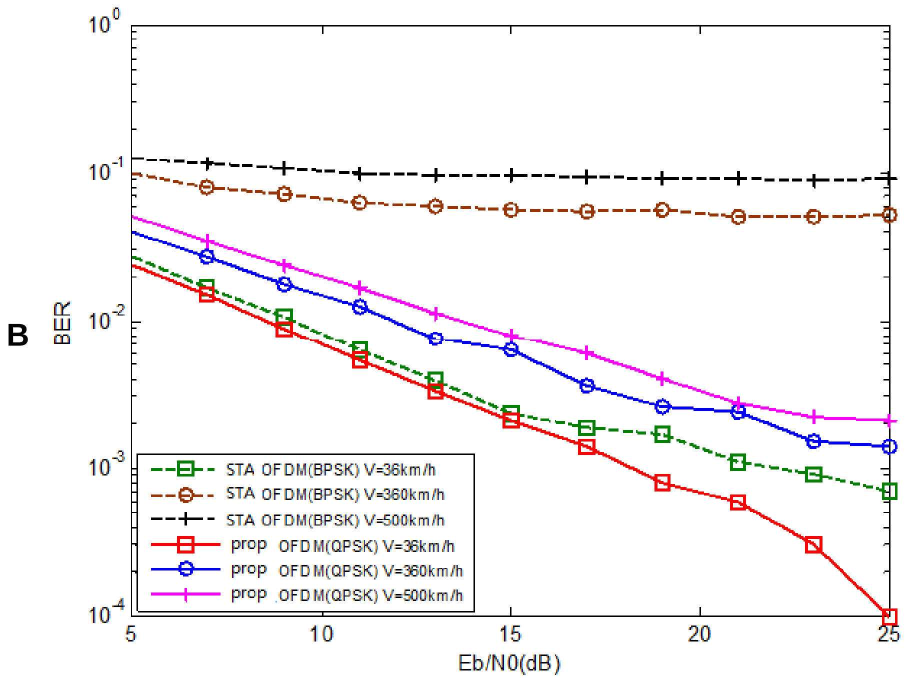
Challenges and Future Work (II)

- V2V communication system design based on realistic channel models
  - Pilot pattern and channel estimator.
  - High intercarrier interference (ICI).

Prof. Yuping Zhao

Yuping Zhao and S.-G. Haggman, “Intercarrier interference self-cancellation scheme for OFDM mobile communication systems,” *IEEE Trans. Commun.*, vol. 49, no. 7, Jul. 2001. (**Cited more than 300 times**)

Yuping Zhao, and S.-G. Haggman, “Intercarrier interference compression in OFDM communication systems by using correlative coding,” *IEEE Communications Letters*, vol. 2, no. 8, pp. 214-216, Aug. 1998. (**Cited more than 100 times**)



E_b/N_o(dB)

Recent Publications Related to This Talk

Journals

[1] Cheng-Xiang Wang, Xuemin Hong, Xiaohu Ge, Xiang Cheng, Gong Zhang, and John Thompson, "Cooperative MIMO channel models: a survey", ***IEEE Commun. Mag.***, vol. 48, no. 2, pp. 80-87, Feb. 2010.

[2] Cheng-Xiang Wang, Xiang Cheng, and D. I. Laurenson, "Vehicle-to-vehicle channel modeling and measurements: recent advances and future challenges", ***IEEE Commun. Mag.,*** vol. 47, no. 11, pp. 96 – 103, Nov. 2009.

[3] Xiang Cheng, Cheng-Xiang Wang, D. I. Laurenson, S. Salous, and A. V. Vasilakos, "An adaptive geometry-based stochastic model for non-isotropic MIMO mobile-to-mobile channels", ***IEEE Trans. Wireless Comm.*** , vol. 8, no. 8, Aug. 2009.

[4] Xiang Cheng, Cheng-Xiang Wang, D. I. Laurenson, S. Salous, and A. V. Vasilakos, "New deterministic and stochastic simulation models for non-isotropic scattering mobile-to-mobile Rayleigh fading channels", ***Wireless Communications and Mobile Computing***, John Wiley & Sons, accepted for publication, 2009.

[5] Xiang Cheng, Cheng-Xiang Wang, D. I. Laurenson, and A. V. Vasilakos, "Envelope level crossing rate and average fade duration of non-isotropic mobile-to-mobile Ricean fading channels", ***IEEE Trans. Wireless Comm.*** , revised version re-submitted for publication, 2010.

[6] Xiang Cheng, Cheng-Xiang Wang, Dave. Laurenson, G. L. Stuber, and A. V. Vasilakos, "Modeling and simulation of wideband MIMO vehicle-to-vehicle channels", ***IEEE J. Sel. Areas Commun.***, submitted for publication, 2010.

11 Conferences papers, including 2 invited papers.

Thanks for your attention !